Cognitive function in congenital heart disease after cardiac surgery with extracorporeal circulation

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Background: **Congenital heart disease (CHD) may cause deleterious effects on cognitive function in children. This study aimed to evaluate the changes of the cognitive and academic functioning in children aged less than 4 years with serious CHD following cardiac surgery with extracorporeal circulation (ECC).**

Methods: **A total of 100 children, aged 0-4 years with cyanotic (35) and acyanotic (65) heart diseases who had undergone cardiac surgery with ECC, were subjected to neuropsychological and behavioral evaluation using the Gesell Developmental Schedule (GDS) before operation and at 1 week, and 1, 3 and 6 months after operation.**

Results: **The GDS scores in the first postoperative week were significantly lower than those before operation, but the scores increased gradually ($P<0.01$). ECC affected the GDS scores after operation, with the cyanotic children being more significantly affected than the acyanotic children. The GDS scores were negatively correlated with the age at each time point. The GDS scores were significantly lower in the cyanotic children than in the acyanotic children at 1 and 3 months postoperatively ($P<0.01$), but there was no significant difference at 6 months ($P<0.05$).**

Conclusions: **After cardiac surgery with ECC, the younger the children who have cardiac surgery, the more significantly the GDS score increases. The ECC mainly affects the cognitive ability and academic performance in cyanotic children in one month postoperatively.**

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Introduction

Congenital heart disease (CHD) is a group of diseases pertaining to anomalies or potential anomalies in the major cardiac or thoracic vessels.[1] The morbidity and detection rate of CHD both show an obvious rising trend. The morbidity of central nervous system injury among adult patients with extracorporeal circulation (ECC) is reported to be >8%, while the proportion of patients in the so-called "sub-clinical state" can be as high as 50%-70%.[2] The first study to test the intelligence level of children with CHD by examining their cognitive function pre- and postoperatively was conducted in 1979.[3] Then, Lim,[4] Dittrich,[5] Hövels-Gürich,[6] and others studied different aspects using different methods.

This prospective study was conducted to investigate the cognitive function of children less than 4 years old selected from the cardiac surgery division of our hospital who had received open-heart surgery with ECC.

Methods

Between October 2006 and May 2007, children with CHD who required open-heart surgery with ECC in our hospital were included in this study. Those were excluded who were lost to follow-up. Finally, a total of 100 children were enrolled (58 males and 42 females; aged 0-4 years and mean±SD: 1.12±0.98): 35 with cyanotic heart disease and 65 with acyanotic heart disease. Cognitive functions of the children were assessed preoperatively and postoperatively at 1 week, 1 month, 3 months, and 6 months by psychologists. Preoperative information of the children was collected (Table 1).

At the operating room, midazolam hydrochloride, vecuronium amine, and fentanyl were subsequently injected for induction of anesthesia. During surgery, anesthesia and muscle relaxation were maintained by intermittent intravenous injections of fentanyl and vecuronium bromide, respectively. After the heart started to beat again, dopamine, dobutamine, milrinone, and other vasoactive drugs were pumped in continuously through the internal jugular vein in order to improve cardiac function. ECC was performed

using a Stocker-SC heart-lung machine with DIDICO membrane oxygenation.

The Gesell Developmental Schedule (GDS) was used to assess the behavior of the children.[7] The items include developmental quotients (DQ) responding to objects, people, movement, and language. DQ <65-75 indicates a serious lag in cognitive functions; DQ <85 in infancy implies injury somewhere in the body.

SPSS 14.0 statistical software was used for the statistical analysis.

Results

The GDS scores of the 4 items of cognitive functioning were low among children with CHD before operation. Compared with the preoperative GDS scores, all corresponding postoperative scores showed an obvious decrease in the first week postoperatively (P<0.01). Subsequently, however, the scores increased significantly at 1, 3, and 6 months (P<0.01), and finally reached the normal level (Table 2).

The regression model showed ECC only affected the GDS scores in the first month postoperatively, and that the effect was greater in the cyanotic group than in the acyanotic group. Only age was negatively correlated with the GDS scores of the 4 items of cognitive functioning in both groups. In the acyanotic group, the ICU stay was negatively correlated with response to people and movement, and the lowest nasopharyngeal temperature was positively correlated with language at one week postoperatively. In the cyanotic group, the cross clamping time was negatively correlated with response to objects, people, movement and language, and the lowest nasopharyngeal temperature was positively correlated with language at one week postoperatively. At one month postoperatively, the acyanotic group showed that ICU stay was negatively correlated with response to people and the cyanotic group showed a negative correlation between the cross clamping time and response to people.

The GDS scores of cognitive functioning in all 4 items in the cyanotic group were obviously lower than those in the acyanotic group preoperatively and at 3 months postoperatively (P<0.01). The values in both groups were almost the same at 6 months postoperatively, with no significant difference (P>0.05). The values, influenced by the ECC technique postoperatively in the first week and first month, were within the range of multiple stepwise regression (Table 3).

Discussion

In the past 50 years, there have been considerable improvements in the methods, techniques, equipment, and anesthetic techniques of ECC open-heart surgery, thus leading to a great decrease in the mortality.[8] Better preoperative care, improvement in surgical skills, better cardiac protection during cardiopulmonary bypass, and optimized postoperative management for preventing complications can lower adverse effects.[9]

In our series, preoperative cardiovascular malformation, hemodynamic changes, regression of growth and development, intolerance to certain activities, and excessive protection by the parents and children themselves[10] led to the poorer preoperative GDS scores of cognitive functioning. Ischemia and hypoxia of organs caused a marked decrease in cognitive functioning of the cyanotic children. Open-heart surgery with ECC

Table 1. Preoperative parameters

Parameters	Means ± SD
Age (y)	1.12±0.98
Weight (kg)	9.11±0.35
Duration of extracorporeal circulation (min)	81.3±40.8
Duration of aorta block (min)	48.8±29.7
The lowest nasopharyngeal temperature (°C)	28.1±2.7
The lowest rectal temperature (°C)	29.0±2.7
Intensive Care Unit stay (d)	2.2±1.6

Table 2. Comparison of the 4 items of the GDS scores at 1 week, and 1, 3 and 6 months postoperatively with the preoperative values

Time points	Response to objects	Response to people	Movement	Language
Pre	85.7±7.7	85.4±8.3	84.6±8.8	85.3±8.4
1 wk post	84.3±7.4*	82.8±7.7*	76.6±7.4*	81.8±7.7*
1 mon post	91.3±5.7*	91.3±6.2*	92.8±6.5*	91.4±6.7*
3 mon post	96.8±5.0*	97.1±5.1*	100.2±5.9*	97.0±5.8*
6 mon post	100.7±4.2*	101.0±4.8*	105.1±5.0*	101.9±5.3*

*: P<0.01, compared with the preoperative values. pre: preoperation; post: postoperation.

Table 3. Responses to objects and people, movement and language in the acyanotic group (n=65) and cyanotic group (n=35) preoperatively and at 3 and 6 months postoperatively

Groups	Response to objects			Response to people			Movement			Language		
	Pre	3 mon post	6 mon post	Pre	3 mon post	6 mon post	Pre	3 mon post	6 mon post	Pre	3 mon post	6 mon post
Acyanotic	87.7±7.4	98.1±4.6	101.3±4.2	87.8±8.1	98.3±4.8	101.5±5.1	87.2±8.7	101.8±5.5	105.7±4.9	87.5±8.7	98.5±5.7	102.6±5.5
Cyanotic	81.6±7.1*	93.9±5.1*	99.2±4.0	80.7±6.8*	95.3±6.1*	99.8±4.4	79.2±6.4*	96.9±5.4*	103.7±5.1	80.9±6.1*	94.0±5.2*	100.4±4.5

*: P<0.01, compared with the acyanotic group. pre: preoperation; post: postoperation.

corrected the cardiovascular malformations, leading to a gradual recovery of the cardiac, cerebral, and pulmonary function as well as the physical strength of the children.

If the duration of cross clamping was excessively long, the cognitive functioning in children with CHD was affected.[11] In the acyanotic group, the ICU stay was negatively correlated with the response to people and movement, because the children in ICU were unable to communicate with their parents and their activities were restricted. When the children were transferred to the wards, they showed signs of "body image disorder".[12] The longer the duration of ICU stay, the more pronounced the effect on the children. The closer the nasopharyngeal temperature was to the physiological conditions, the smaller was the effect on the throat, mouth, and other organs involved in speech.

In the first postoperative month, the duration of cross clamping was correlated negatively with the response to objects and people because the mechanisms of response to objects and people were more complex than those of response to movement and language. Moreover, the negative impact required more time to diminish completely. The response to people in the acyanotic group was affected by the duration of ICU stay, indicating that treatment in the ICU was an unpleasant experience in the memory of most children.

The speed of early development of the cranial nerves is high. With age, the cumulative effect[11,13] of long-term ischemia and hypoxia of the brain and other important organs resulted in a negative correlation between the age and GDS scores on cognitive functioning at each time point in both groups. The effects of the duration of cross clamping and the nasopharyngeal temperature gradually disappeared with time. The "body image disorder" observed during the ICU stay passed the period of conflict and entered into the periods of retreat, recognition, and reconstruction.[12]

In general, open-heart surgery with ECC in 0-4-year-old children with CHD is advantageous for the development of the body and cognitive functioning. The interventions according to practical demands (1) will improve cognitive and neural functions; (2) reduce or eliminate different kinds of psychological stress, negative emotion, abnormal behavior, and various somatic symptoms caused by them; and (3) improve the overall rehabilitation, life quality, and the family and social functioning of children with CHD.[14]

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